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LUNAR PHYSICAL PARAMETERS STUDY PROGRAM

PARTIAL REPORT NO. 14

BREADBOARD TESTS OF THE SUBSURFACE MAGNETIC SUSCEPTIBILITY COILS

WORK PERFORMED UNDER J.P.L. CONTRACT NO. N-33552

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BREADBOARD TESTS OF THE SUBSURFACE MAGNETIC SUSCEPTIBILITY COILS

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Introduction

The results of the feasibility study concerning the measurement of magnetic susceptibility on the surface of the moon, as presented in Partial Report No. 7, were, briefly, as follows:

1. Variation of the mutual and self inductance of a three coil inductive balance system, consisting of a split receiver coil, placed in a borehole drilled into the lunar surface could be employed to measure the magnetic susceptibility of the material adjacent to the borehole.
2. The response of this system to variations in borehole diameter are predictable, and suitable corrections can be made if borehole diameter is known.
3. The range of measurement with the coil is 1×10^{-6} to $100,000 \times 10^{-6}$ cgs units.

Object

To obtain performance data as described in Outline of Breadboard Test Experiments.

Description of Apparatus

The subsurface coils were built as shown in Fig. 1. In this figure it is seen that there are two receiver coils and one transmitter coil located on 1-1/4 in. centers. The two outside receiver coil spools house 300 turns of No. 32 copper wire. The center transmitter coil spool houses 600 turns of No. 32 copper wire. A groove has been cut in the epoxy housing connecting the three coil forms so connections can be made externally. A 1/4 in. hole was drilled along the axis of the coil spool to facilitate passage of non-magnetic wires to other instruments located below the coils in the subsurface instrument. The receiver coils are connected in series so that their magnetic fields are aiding.

Fig. 2 shows a set of coils which are located on the surface in a field of environment that will remain magnetically constant. This set of coils is made up of one transmitter coil containing 600 turns of No. 32 copper wire and one receiver coil made up of 500 turns of No. 32 copper wire. The coils are mounted on an epoxy rod which is threaded, nuts are screwed on the holding rod with the coils placed between them. This method of mounting is used because an adjustment must be made mutually between the transmitter and receiver coils for optimum performance.

The three coils located on the subsurface sonde must be wound with wire, connected electrically, and vacuum impregnated before installation into the sonde. Fabrication of the subsurface sonde requires that all the measuring instruments be built and ready to install at the same time. This has to be done because electrical wires running to instruments below the coils must run through the center of the coils to get to the surface. These wires must be made of non-magnetic materials and be held rigidly in position. Fig. 2 is a drawing showing the positions of the subsurface coils on the sonde and the null coils on the surface.

With the bridge connected to the coils as shown in Fig. 3, the correct position of the coils on the surface set is determined by first placing the sonde and the surface set in air, and secondly by setting the bridge resistors at approximately the value desired. The position of the receiver coil with reference to the transmitter coil is varied until a null is obtained. For a complete null a change in the bridge setting is required to match the phase relationship of the signal from the coils to that of the bridge.

To make measurements, the bridge is nulled with both sets of coils in air and the reading is recorded. The bridge is then nulled again and reading recorded after the subsurface sonde has been placed in a borehole which has been drilled into the material in question. The difference in the readings is a function of the magnetic susceptibility of the unknown material.

Results

Fig. 4 is a plot of change in bridge reading in going from air to the standard vs. the magnetic susceptibility of the standard for boreholes of 1-1/4 in. diameter and 1-3/4 in.

diameter. The magnetic susceptibility of the standard was determined previously by a method outlined in Partial Report No. 11. The 1-1/4 in. and 1-3/4 in. boreholes were made by inserting 32 mm diameter and 45 mm diameter standard wall pyrex glass tubing into the 3 ft. x 3 ft. x 18 in. standards. In Fig. 4 it can be seen that the change in bridge reading in going from a 1-1/4 in. to a 1-3/4 in. borehole of the same standard causes a decrease in ΔR_3 of 50% in the low magnetic susceptibility standards and approximately 37% in the high magnetic susceptibility standards. The 1-1/4 in. borehole has 1/2 the cross sectional area of the 1-3/4 in. borehole, therefore, it is reasonable to assume that the response should decrease 50%. Less error due to hole size variations exist in the high magnetic susceptibility standards because of the demagnitization effect.

The subsurface coil can be no closer than 6 in. to large metal plates or manipulating hardware if an accurate reading is to be made. However, if the metal is of the non-magnetic type and is at least 1 in. from the coils along the body of the sonde an accurate calibration in air could be made. This same distance should be maintained above the opening to the borehole.

Discussion

The experimental results obtained by the Laboratory as described in Outline of Breadboard Test Experiments indicate that it is possible to describe a calibration curve for the subsurface instrument over the desired range of 1×10^{-6} to $100,000 \times 10^{-6}$ cgs units. A maximum error of 50% exist in going from a 1-1/4 in. borehole to a 1-3/4 in. borehole. This error can be minimized to within a few percent if the diameter of the borehole adjacent to the coils is accurately known. A non-magnetic environment must surround the magnetic susceptibility portion of the subsurface sonde to get a reference reading in air. The reference coils must be located in an environment that does not change during the time between the reference reading and the reading made in unknown material. The elapsed time between reference reading and reading made in unknown material should be a minimum. No data were taken to determine the feasibility of making corrections for temperature changes occurring between reference and readings in unknown material, however, very little change should occur with proper materials of construction.

Conclusions

1. The operating range of the device is from $(1 \text{ to } 100,000) \times 10^{-6}$ cgs units of magnetic susceptibility.

2. A correction can be made for borehole diameter variations.

3. With approximately 6 in. of distance between the spacecraft manipulating hardware and the lunar surface a reference reading can be made.

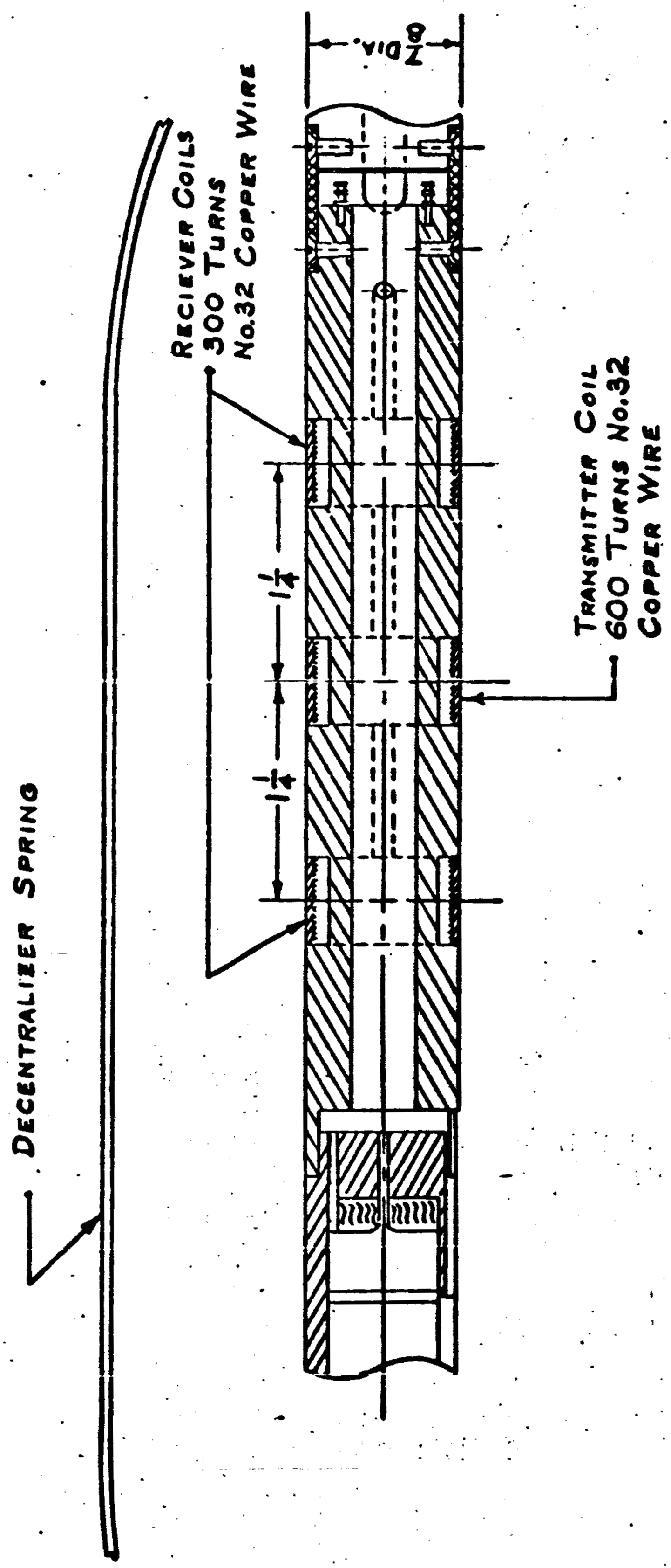

FIGURE 1
SUBSURFACE MAGNETIC
SUSCEPTIBILITY COILS

1:794.41-6
1:794-90

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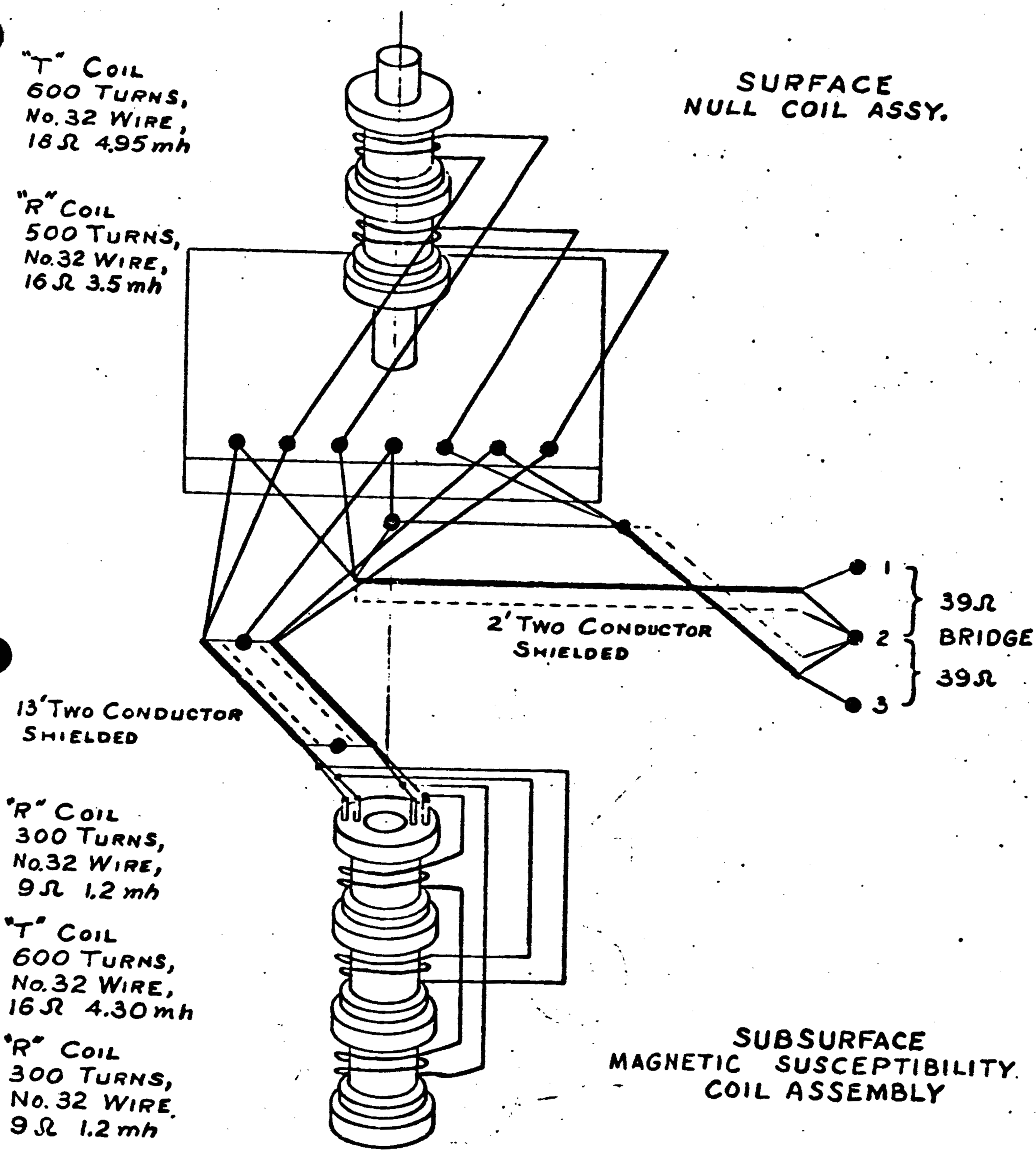

FIGURE 2

1:794.41-7
1:794-91

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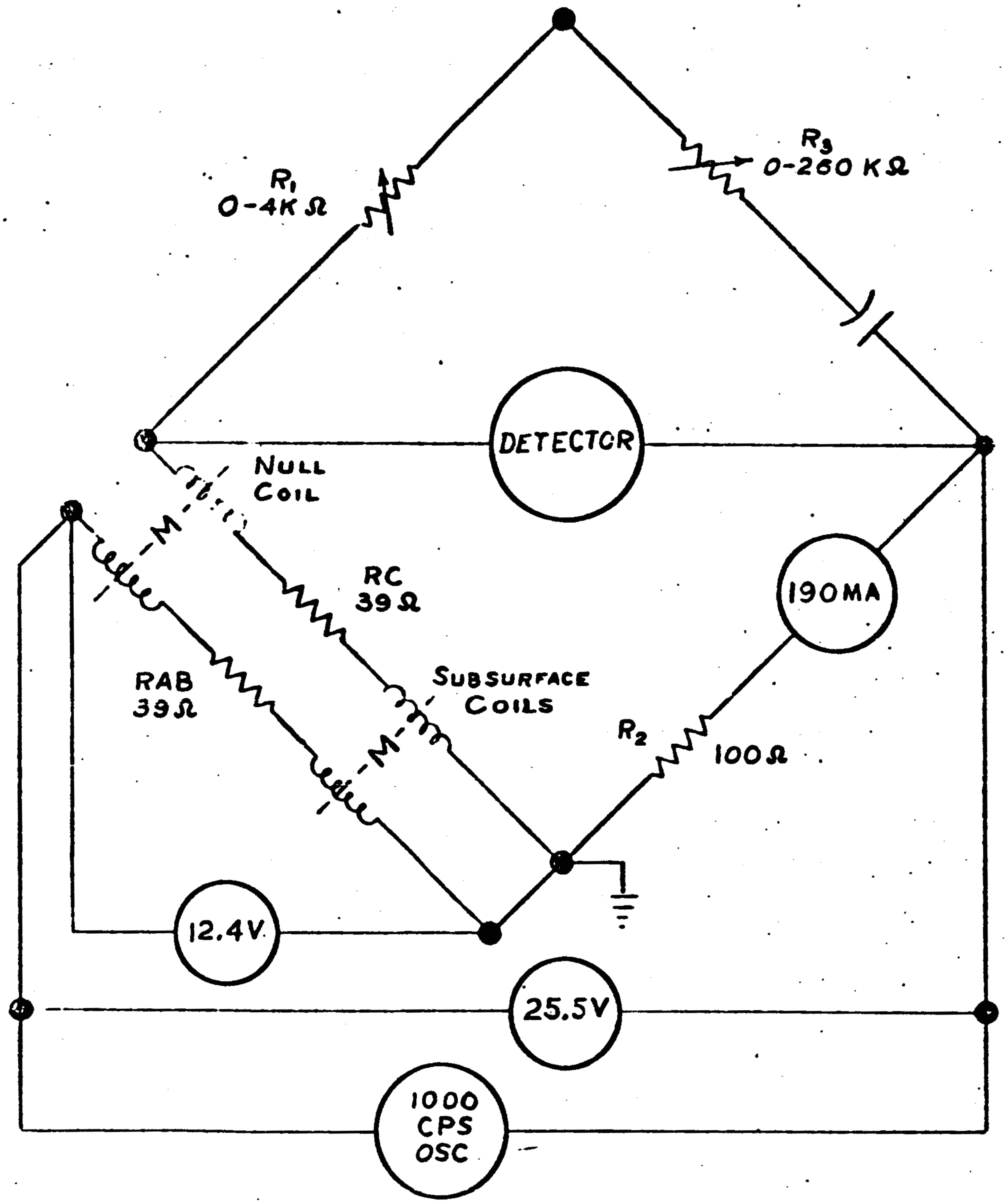
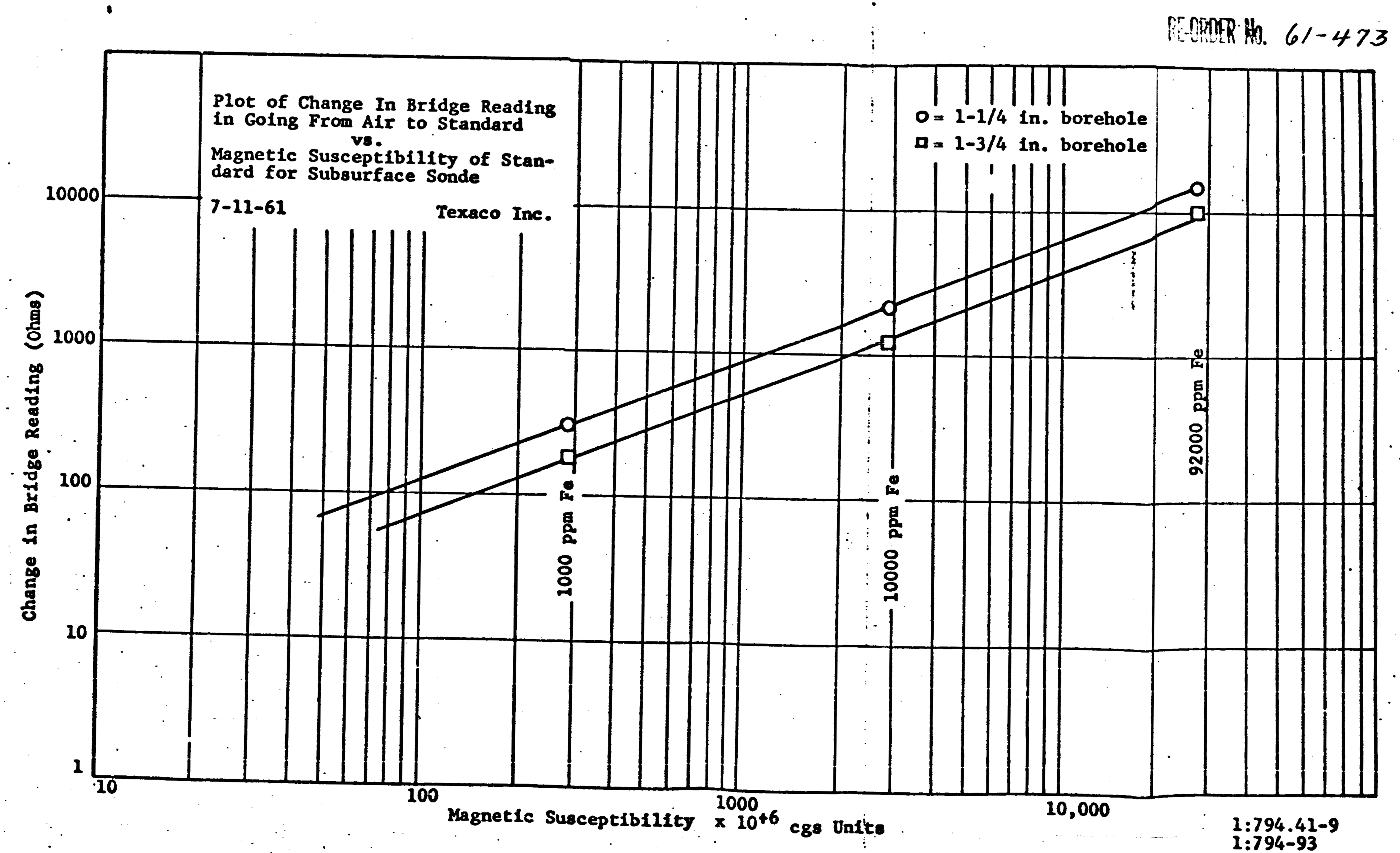


FIGURE 3
COILS & BRIDGE WIRE DIAGRAM
FOR SUBSURFACE MAGNETIC
SUSCEPTIBILITY INSTRUMENT

1:794.41-8
1:794-92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Plot of Change In Bridge Reading
in Going From Air to Standard
vs.
Magnetic Susceptibility of Standard for Subsurface Sonde
7-11-61
Texaco Inc.
O = 1-1/4 in. borehole
□ = 1-3/4 in. borehole
1000 ppm Fe
10000 ppm Fe
92000 ppm Fe
Change in Bridge Reading (Ohms)
10000
1000
100
10
1
10
100
1000
10,000
Magnetic Susceptibility x 10+6 cgs Units
1:794.41-9
1:794-93